Unsteady Assessments and Improvements for the National Transonic Facility

Greg Jones, Ph.D.
Configuration Aerodynamics Branch

OUTLINE

- OBJECTIVES
- OVERVIEW OF NTF STARBUKS AND FIDO EFFORTS
- NTF CENTERLINE PIPE TEST
- NTF RAKE TEST
- NTF COMMON RESEARCH MODEL TEST
- CONCLUDING REMARKS

AERIAL VIEW OF NTF

Wind Tunnel Improvements Objectives focus on NTF

	General Wind Tunnel Requirements
No. 1	**Accuracy and Validation** **(Repeatability/Data Quality)** – Results that can be trusted
No. 2	**Productivity** – Complete required testing in a timely manner
No. 3	**Reliability** – Keeps working without interruption

NTF – Recent Efforts

- **S**ubsonic **T**ransonic **A**pplied **R**efinements **B**y **U**sing **K**ey **S**trategies ***(STARBUKS)***
- **F**acility **I**mprovements and **D**ata **O**ptimization ***(FIDO)***

STARBUKS SUMMARY

Accuracy & Validation

- ☑ Data Acquisition System (Test SLATE)
- ☑ Mach Measurement System
- ☑ Facility Automation System
- ☑ Cooling Coil Trailing Edge Fairings
- ☑ Fixed Fairing Extension
- ☑ Alt. Probes Location (RTD on Cooling Coil)
- ☑ Test Section Visibility
- ☑ Balance Calibrations

Productivity

- ☑ Cryogenic Active Damper
- ☑ Balance Limit Alarm (BLAMS) Upgrade
- ☑ Inlet Guide Vane (IGV) ΔT Mitigation
- ☑ Continuous Pitch

Reliability

- ☑ High Pressure Air Reducing Station
- ☑ Drive Coupling
- ☑ IGV Hydraulic Pipe Repair

IMPROVED NTF

Phase I Testing

- ✓ Check Std Test 214 — Check Standard Model
- ✓ CRM Test 215 — Common Research Model

☑ Completed

Phase II Testing

- ✓ Flow Calibration Test 217
- CRM Data Flow Quality ✓ Test 218

See Paryz AIAA 2014-1481

FIDO IMPROVEMENTS ROADMAP

Accuracy & Validation

- ☐ Tunnel configuration selection
- ☐ Free stream Turbulence (Rake – TBD)
- ☑ Mach stability ±0.0005
- ☑ Conditional sampling (off-line)
- ☑ Validate RTD array on cooling coil

Productivity

- ☐ Mach control methodology
- ☐ 2nd throat actuation
- ☐ Conditional sampling (on-line, real-time)
- ☐ Increase access housing heating
- ☐ Optimized nitrogen injection
- ☑ Continuous sweep

Reliability

- ☐ Liquid nitrogen pump health monitoring
- ☐ Minimize nitrogen system hammering

IMPROVED NTF

Phase I Testing

- ✓ Check Std Test 219
- ✓ Flow Survey Rake Test 216A

☑ Completed

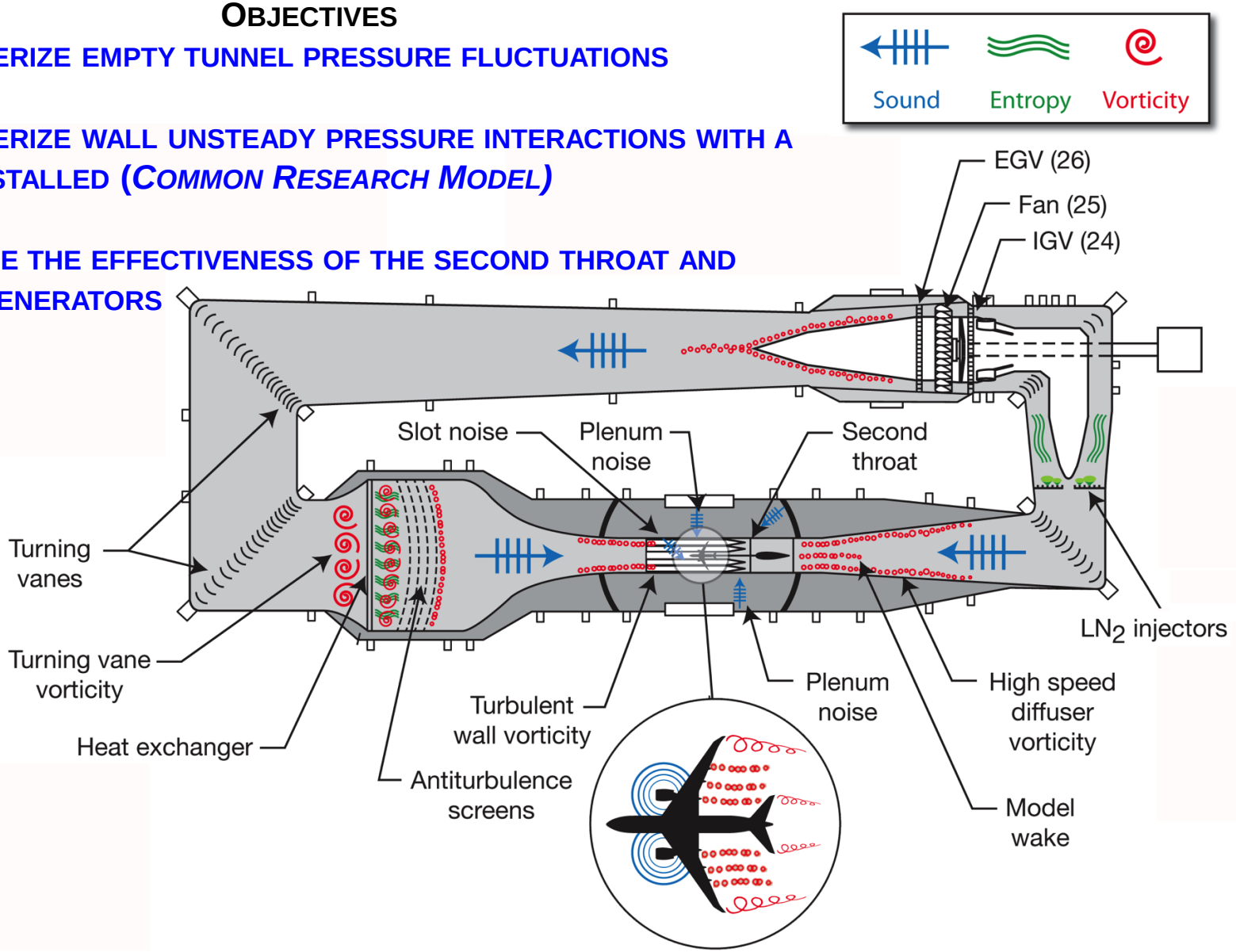
Phase II Testing

- Calibration Extension Test 220
- Turbulence Survey Rake Test 216B
- CRM Test 221

NTF Unsteady Characteristics that can Influence Mach Stability and Data Quality

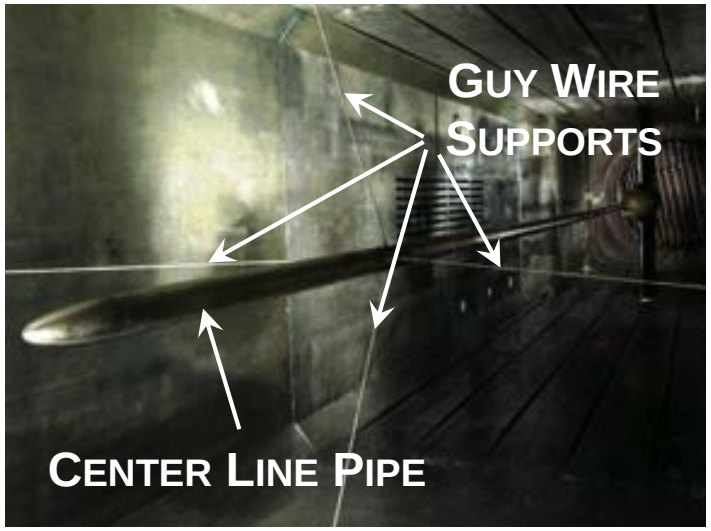
Objectives

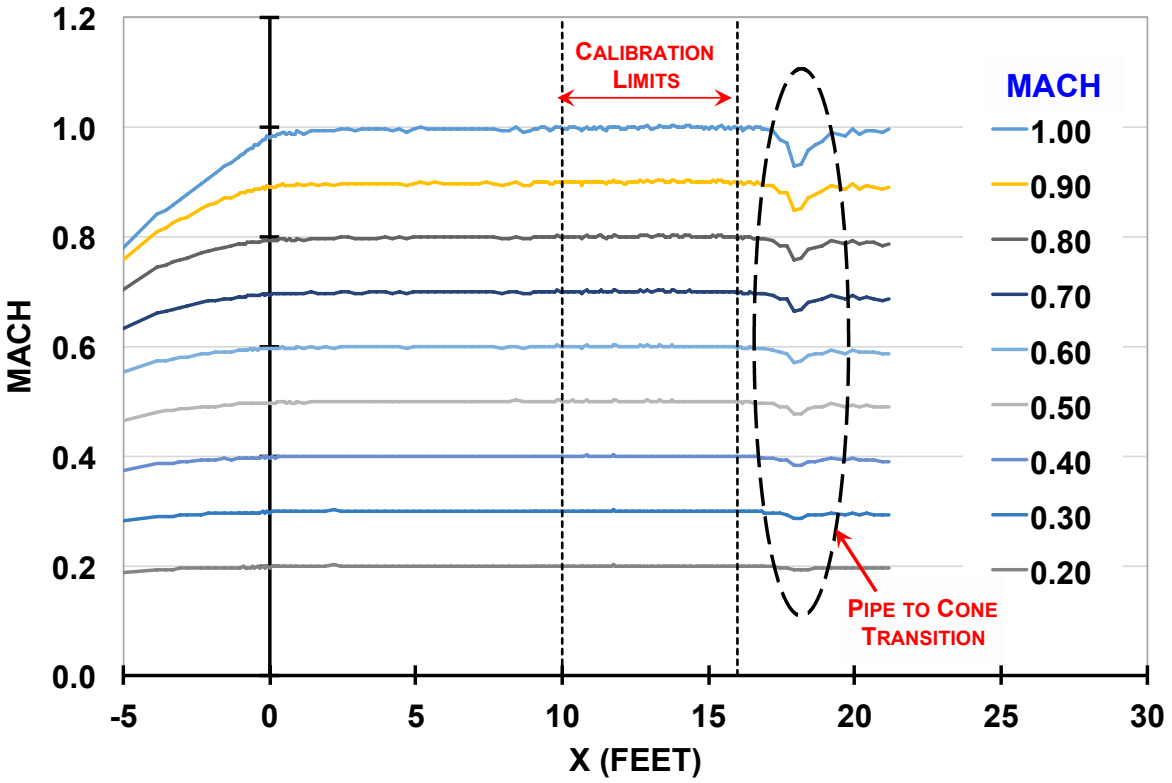
- Characterize empty tunnel pressure fluctuations
- Characterize wall unsteady pressure interactions with a model installed (*Common Research Model*)
- Determine the effectiveness of the second throat and vortex generators



CENTERLINE PIPE TEST

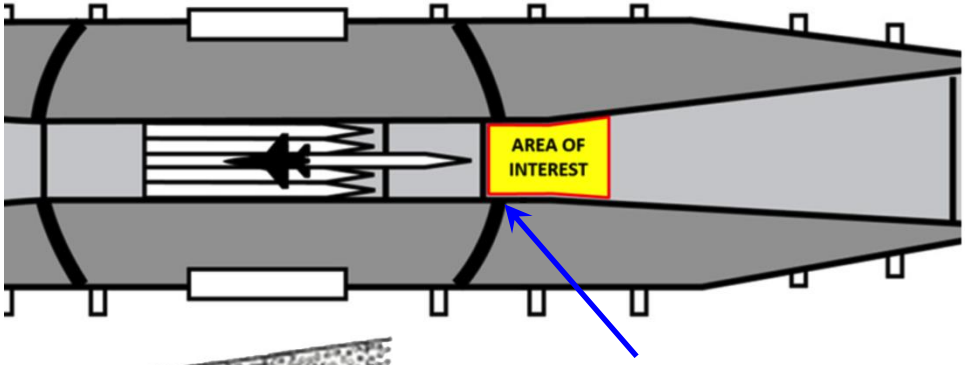
CENTERLINE PIPE DATA TO BE USED FOR TUNNEL CALIBRATION



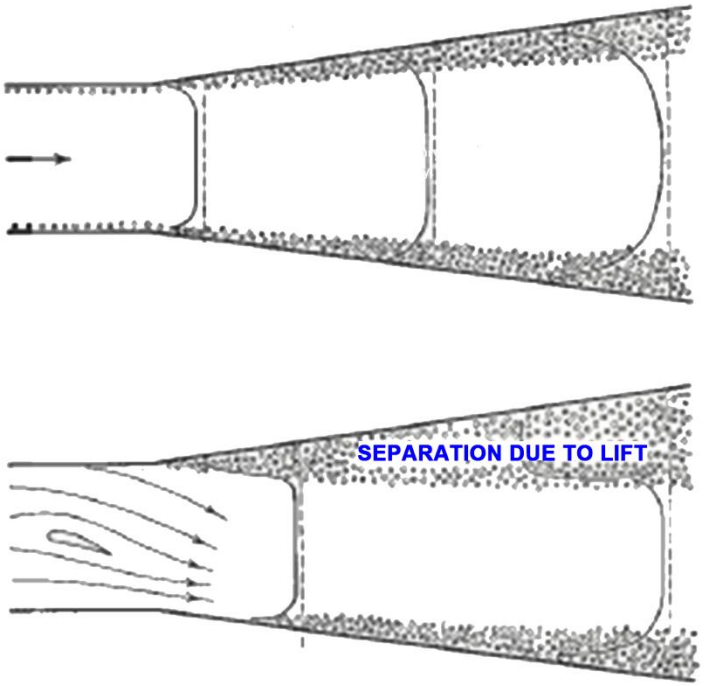


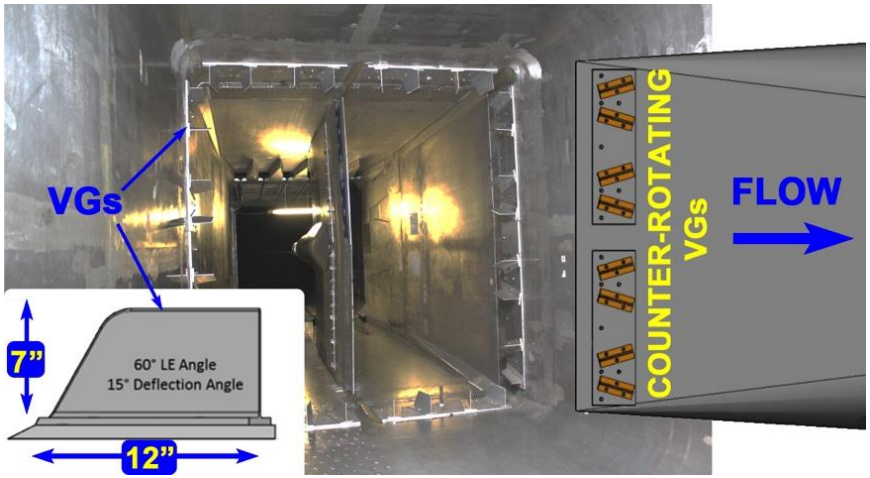
VORTEX GENERATORS

VORTEX GENERATORS ADDED TO MANAGE HIGH SPEED DIFFUSER SEPARATION



VGS LOCATED AT STATION 36’

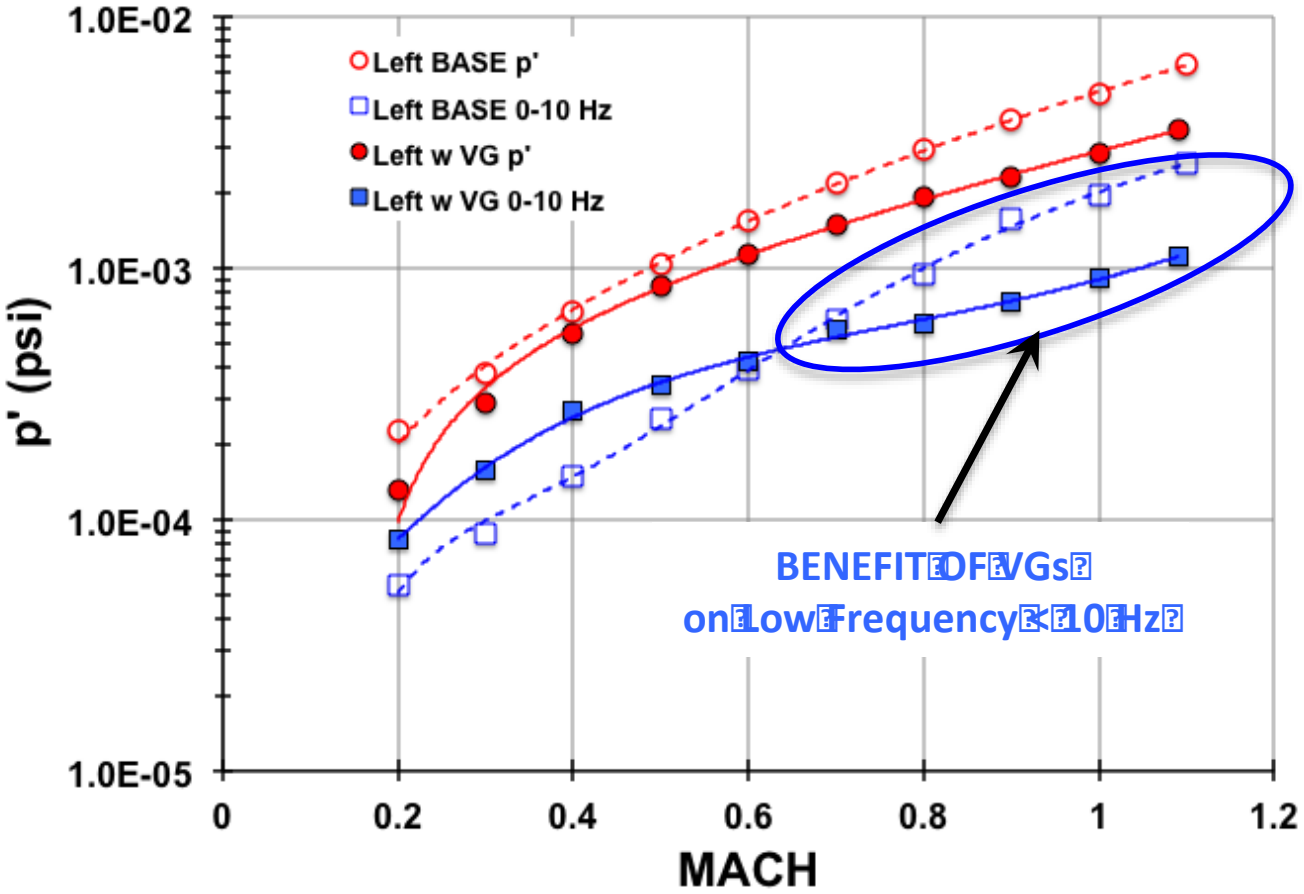




VG SIZE AND SHAPE ARE NOT OPTIMIZED

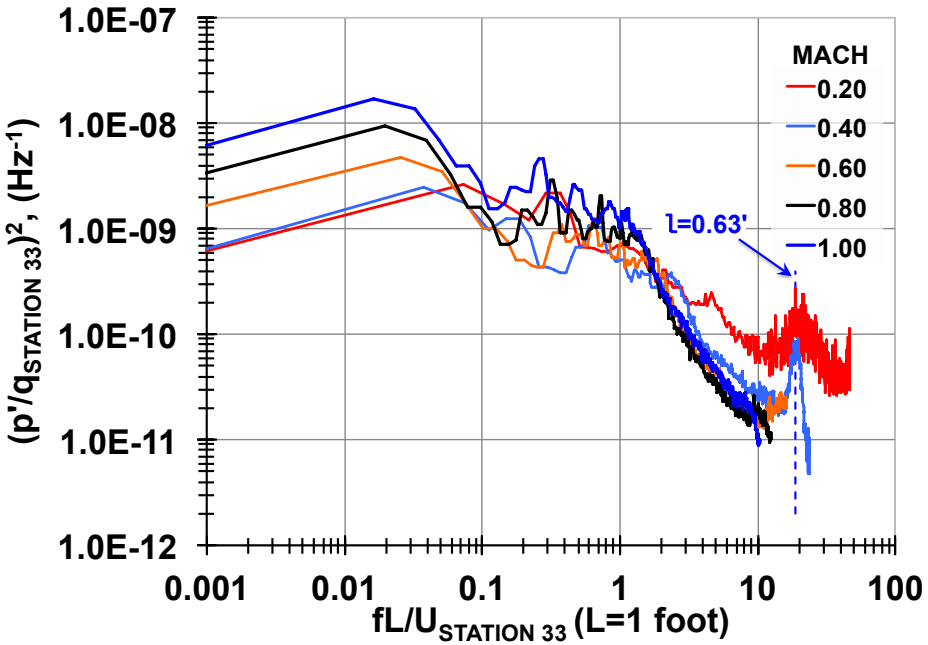
BENEFITS OF VGS
EMPTY TUNNEL

VGS BENEFIT LOW FREQUENCY STABILITY ABOVE MACH ~ 0.7

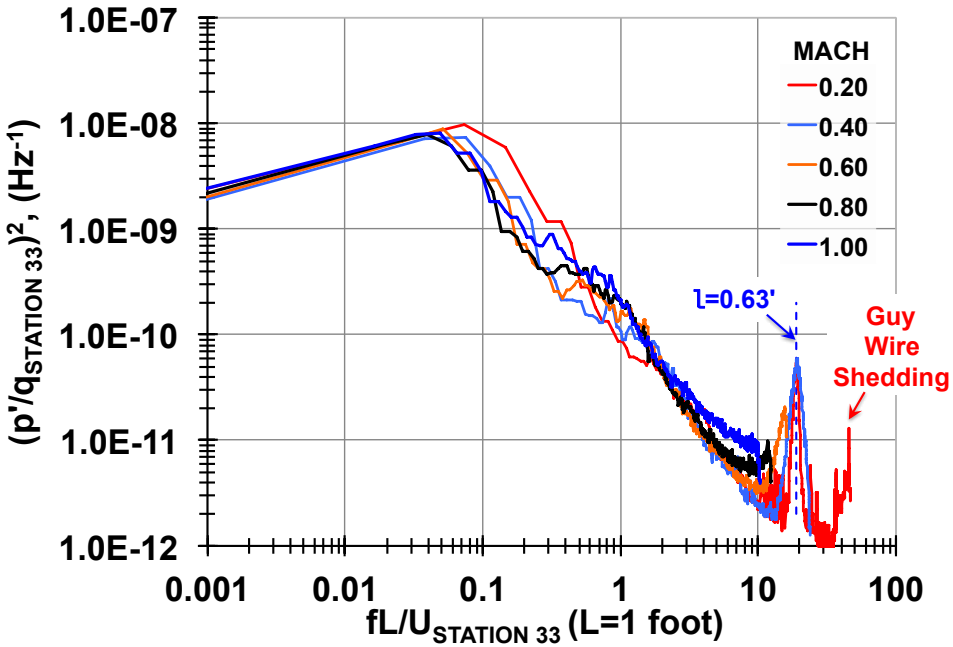


BENEFITS OF VGS (SPECTRA) EMPTY TUNNEL

VGS SHOW BENEFIT FOR EMPTY TUNNEL
(STABILIZES LOW FREQUENCY AND REDUCES BROADBAND)

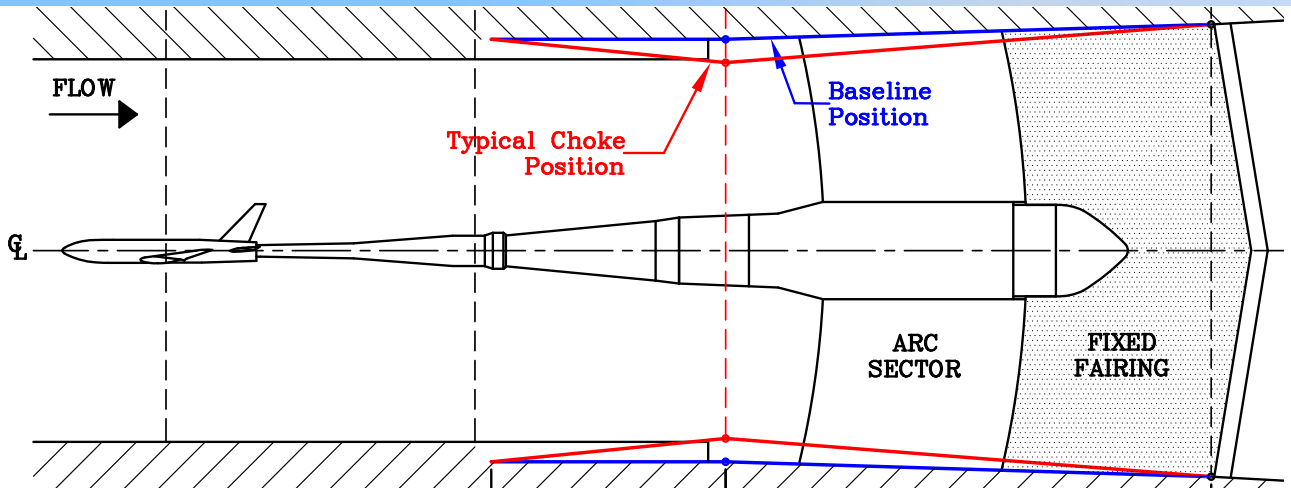


BASELINE

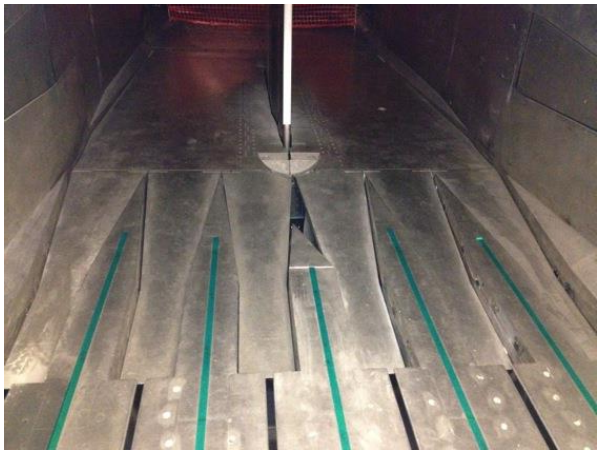


w/ VGs

TEST SECTION MOVABLES (2nd THROAT)

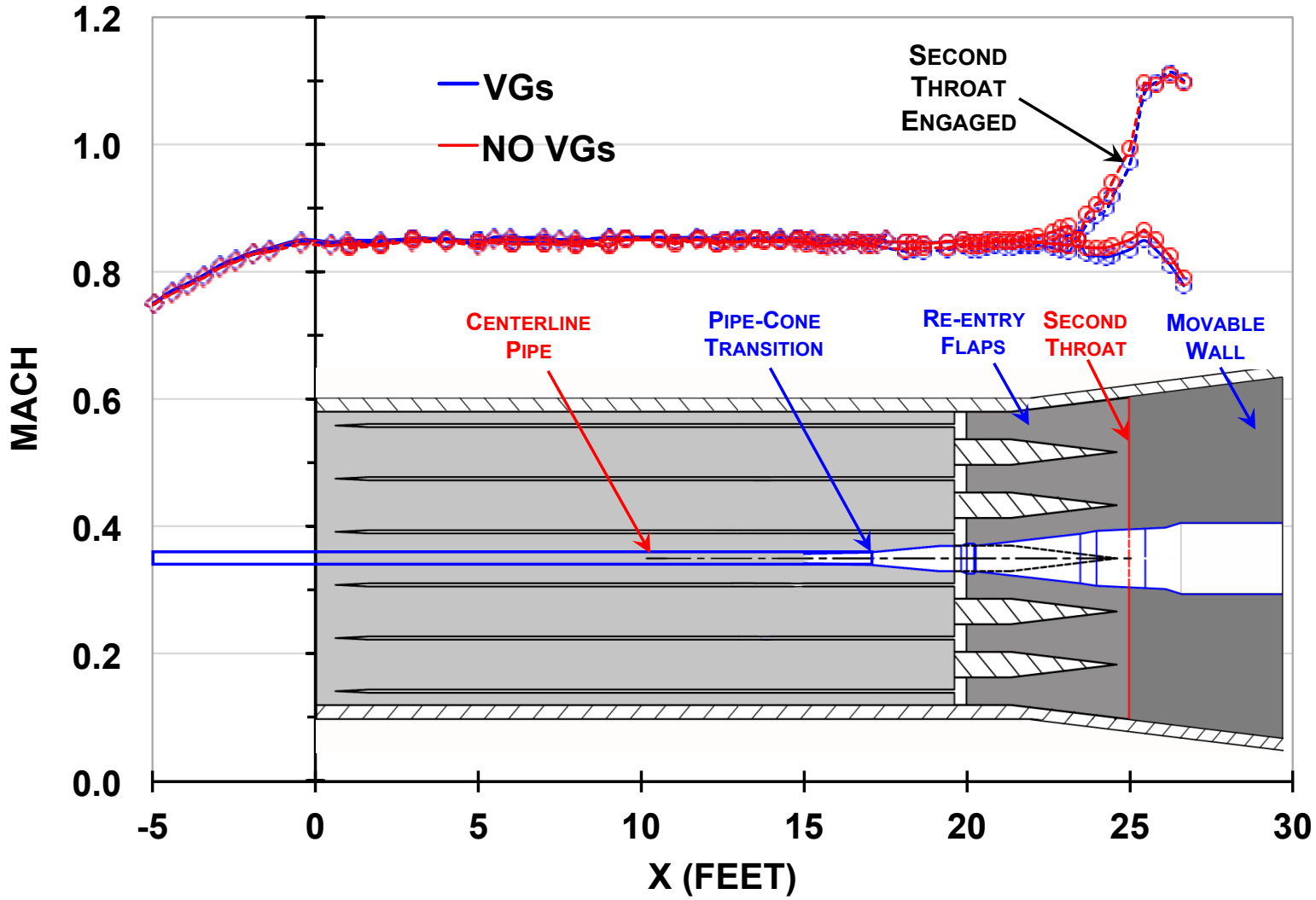


- **Improve Mach stability goals**
  - Target ±0.0005 Mach number for transonic conditions
  - Determine the influence of Mach stability on performance repeatability (e.g., Cd~0.0001)
- **2nd Throat development**
  - Develop a remote positioning system
    - Develop a motorized 2nd throat with a robust instrumentation package to determine wall position
    - Develop a remote wedge system for the fixed faring to minimize support system induced dynamics
- **Planned to be operational in Summer 2015**
- **Requires calibration extension**



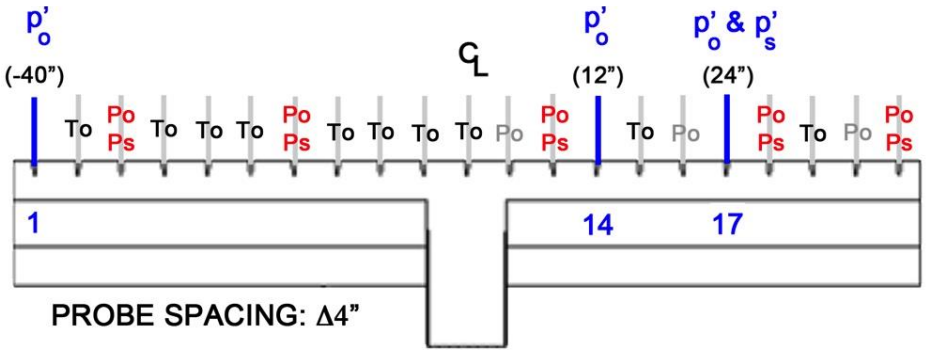
Chan AIAA 2015-0622 and Jones AIAA 2015-1557

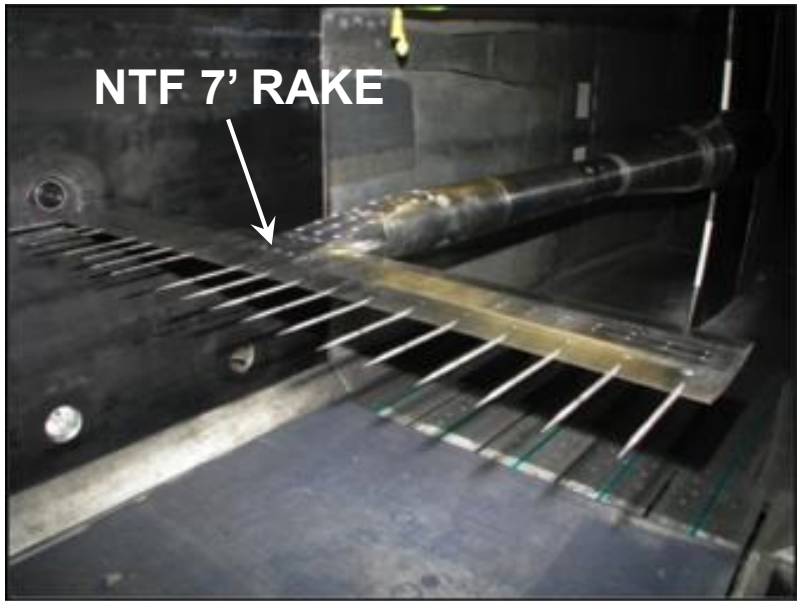
2nd Throat w/ Centerline Pipe Configuration

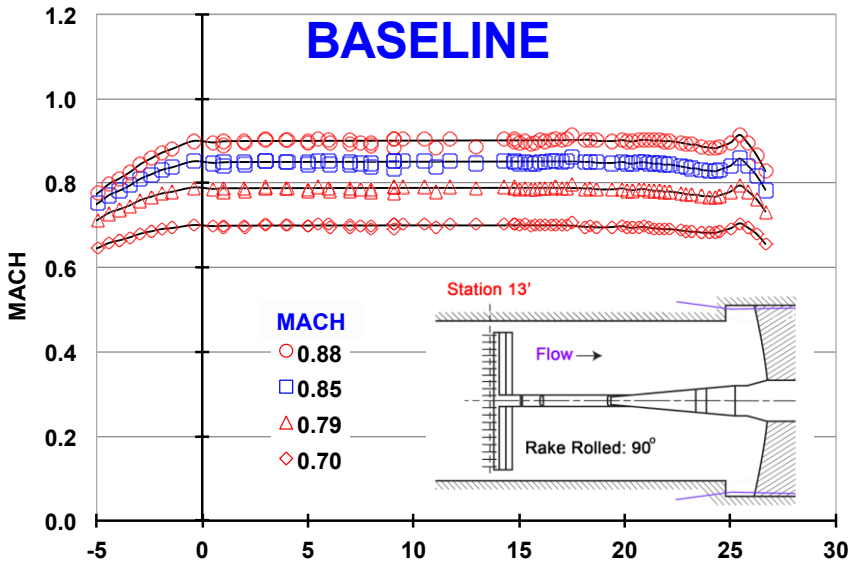


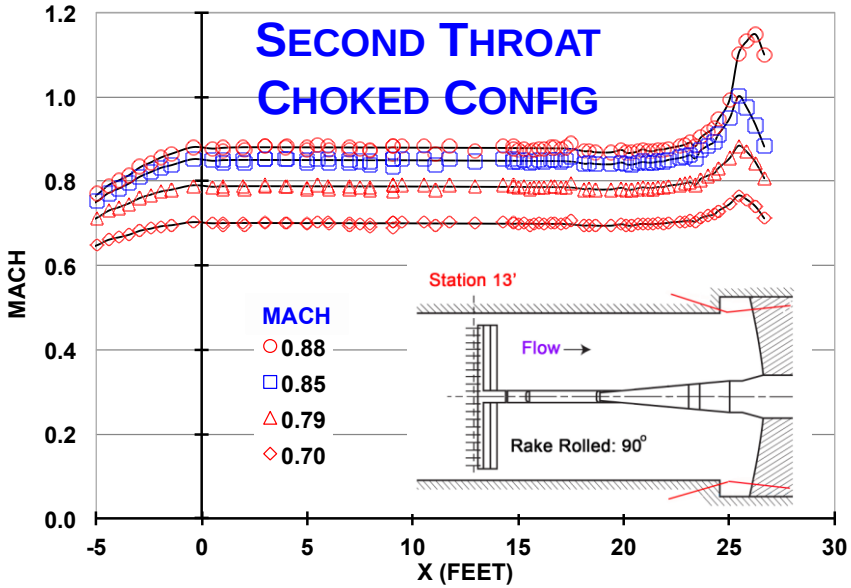
RAKE TEST

RAKE DATA TO BE USED FOR EVALUATING FLOW UNIFORMITY





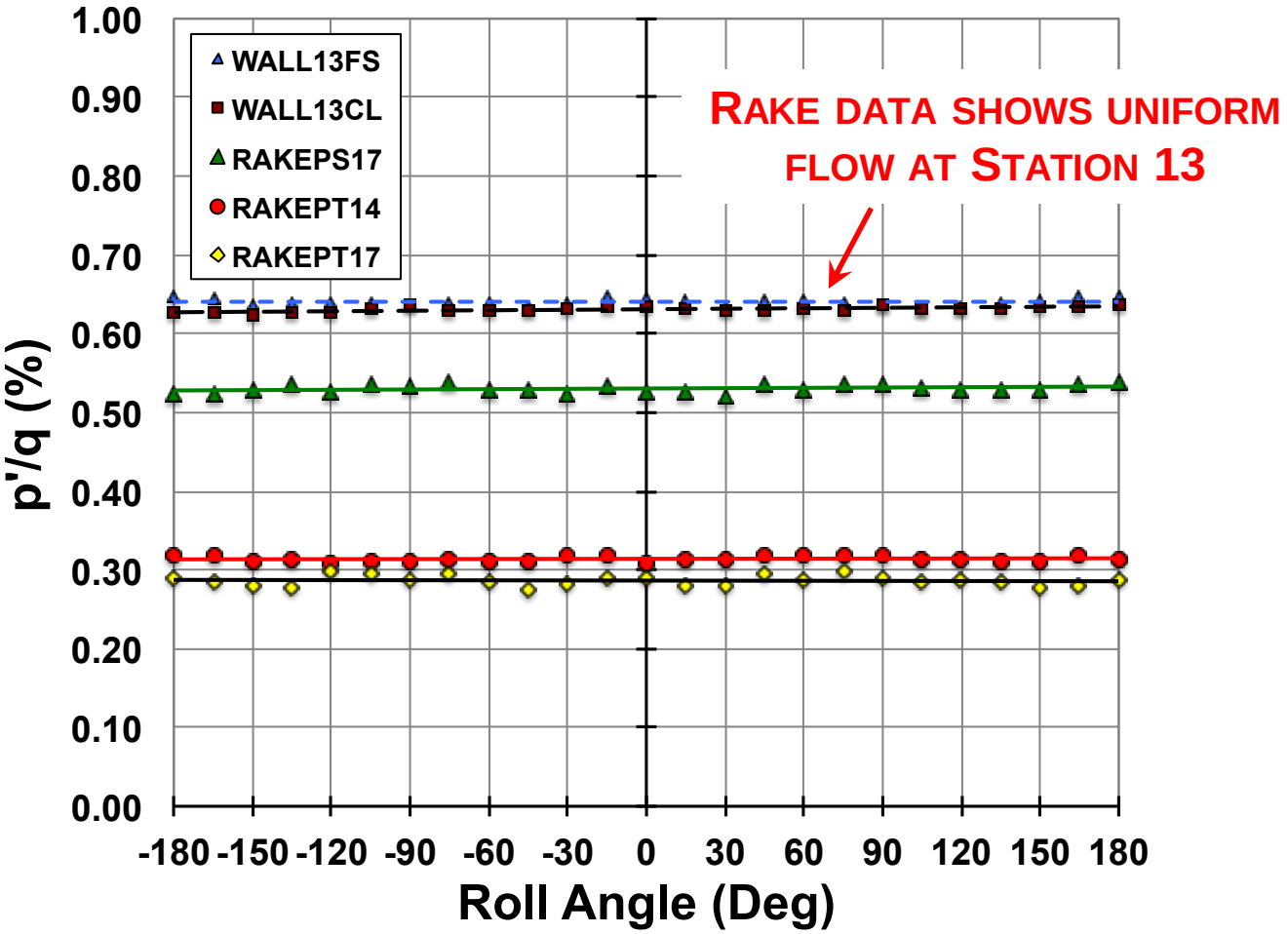




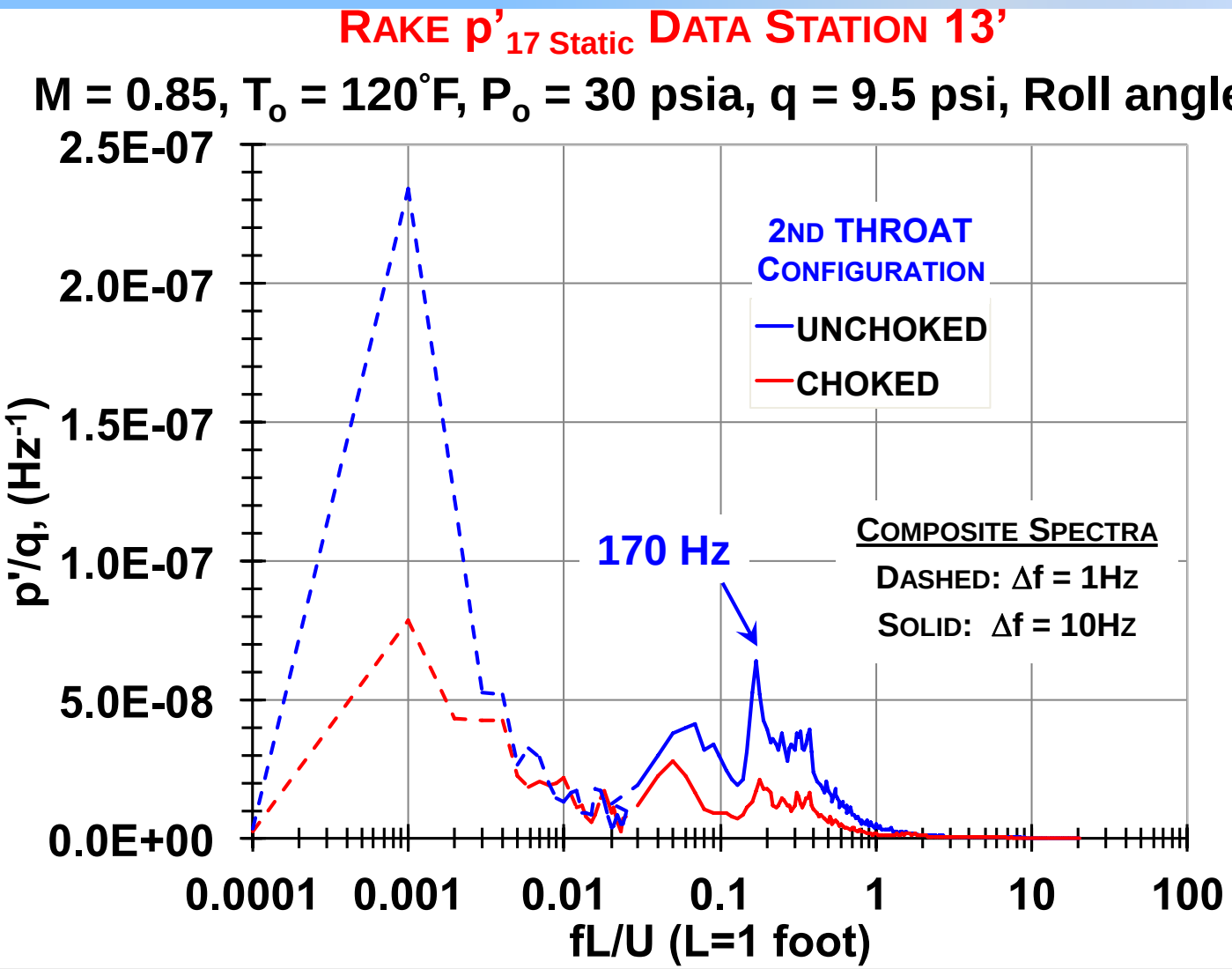
RAKE TEST SECTION UNIFORMITY

M = 0.85, Re/ft = 49.4x10^6, T_o = -251°F, P_o = 44 psia

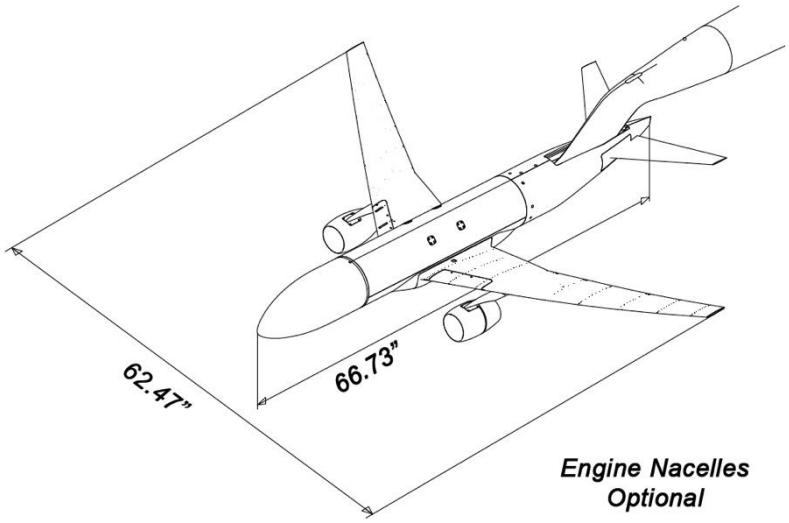
SECOND THROAT CHOKED CONFIGURATION

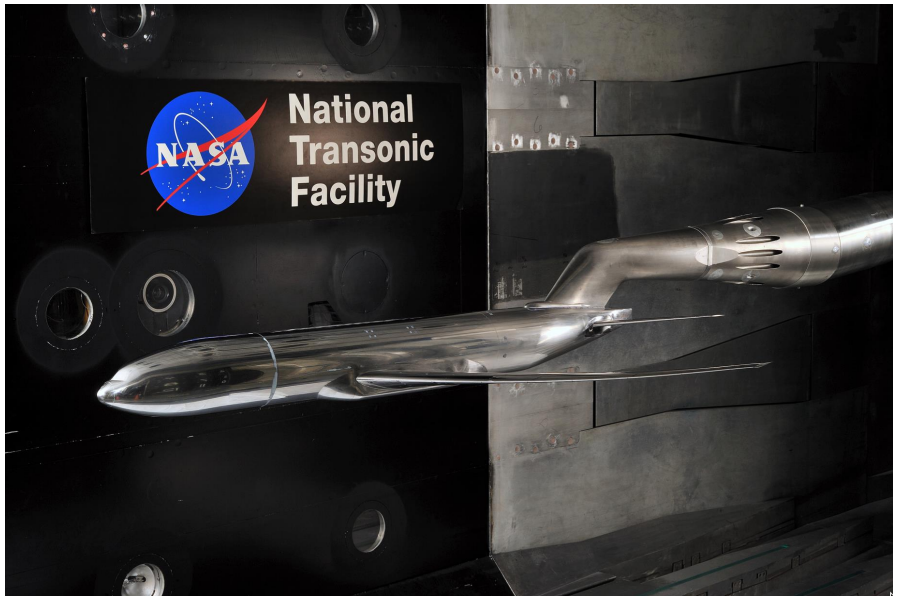


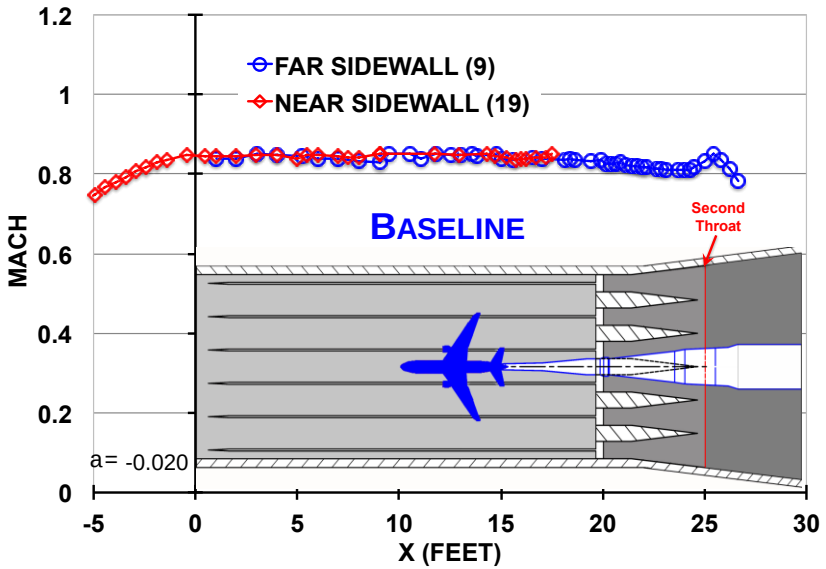
COMPARISON OF CHOKED AND UNCHOKED CONDITIONS

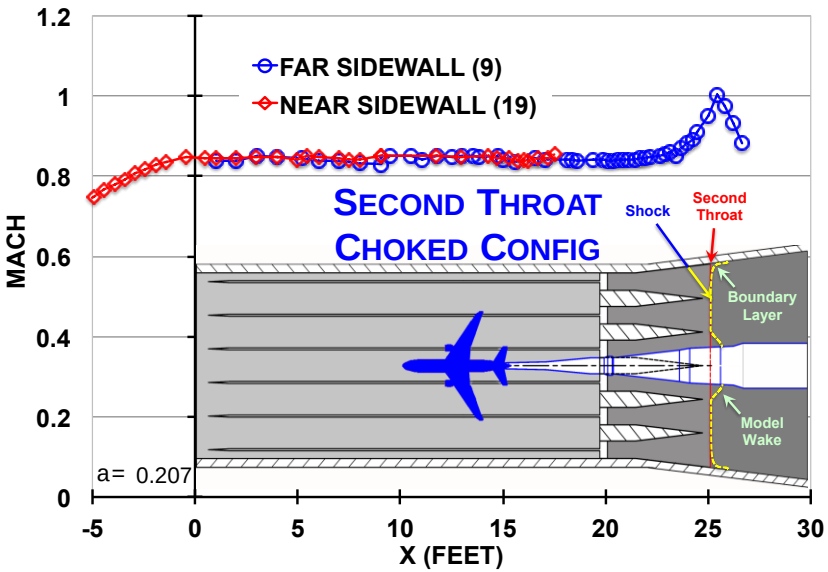


COMMON RESEARCH MODEL TEST

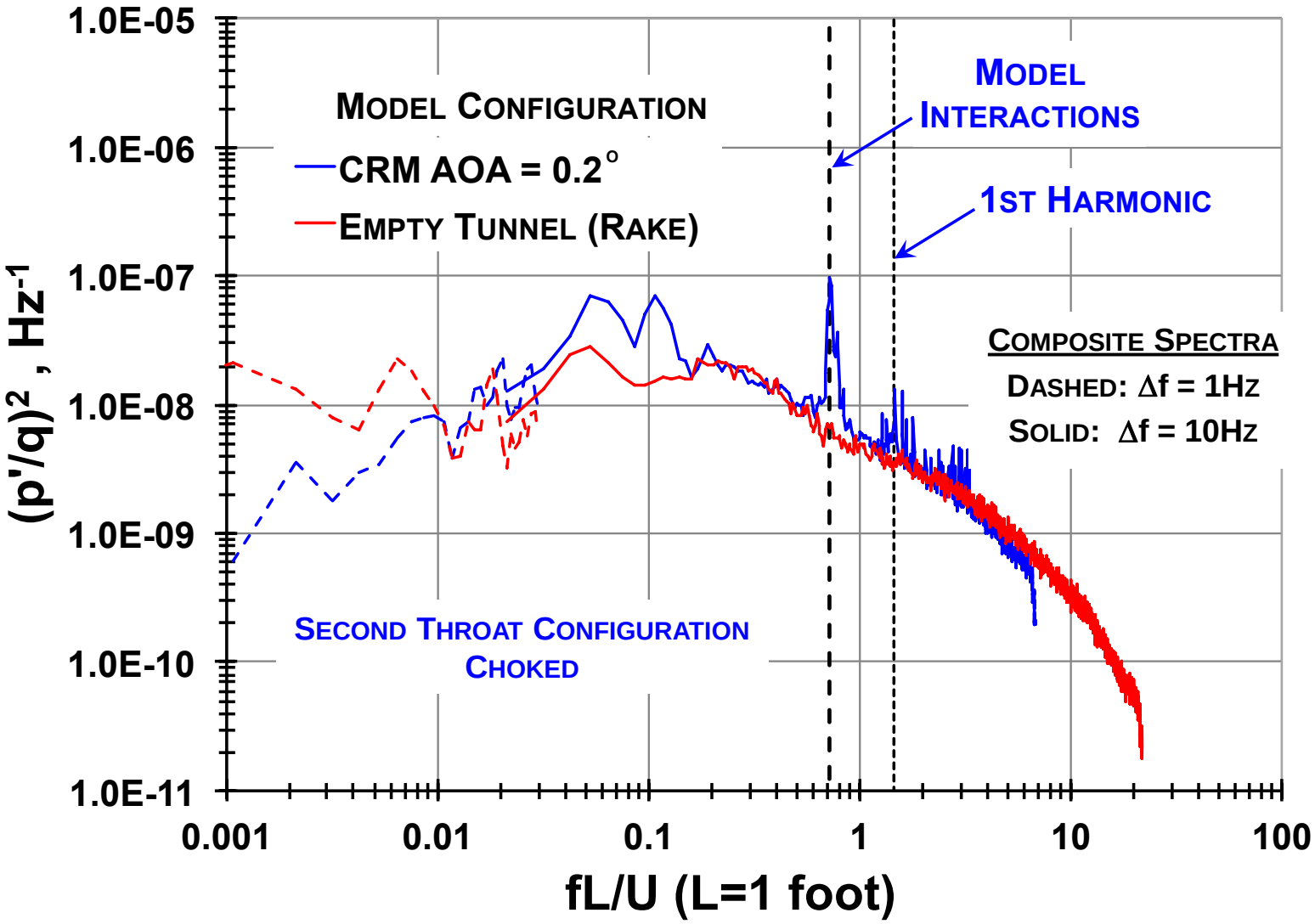




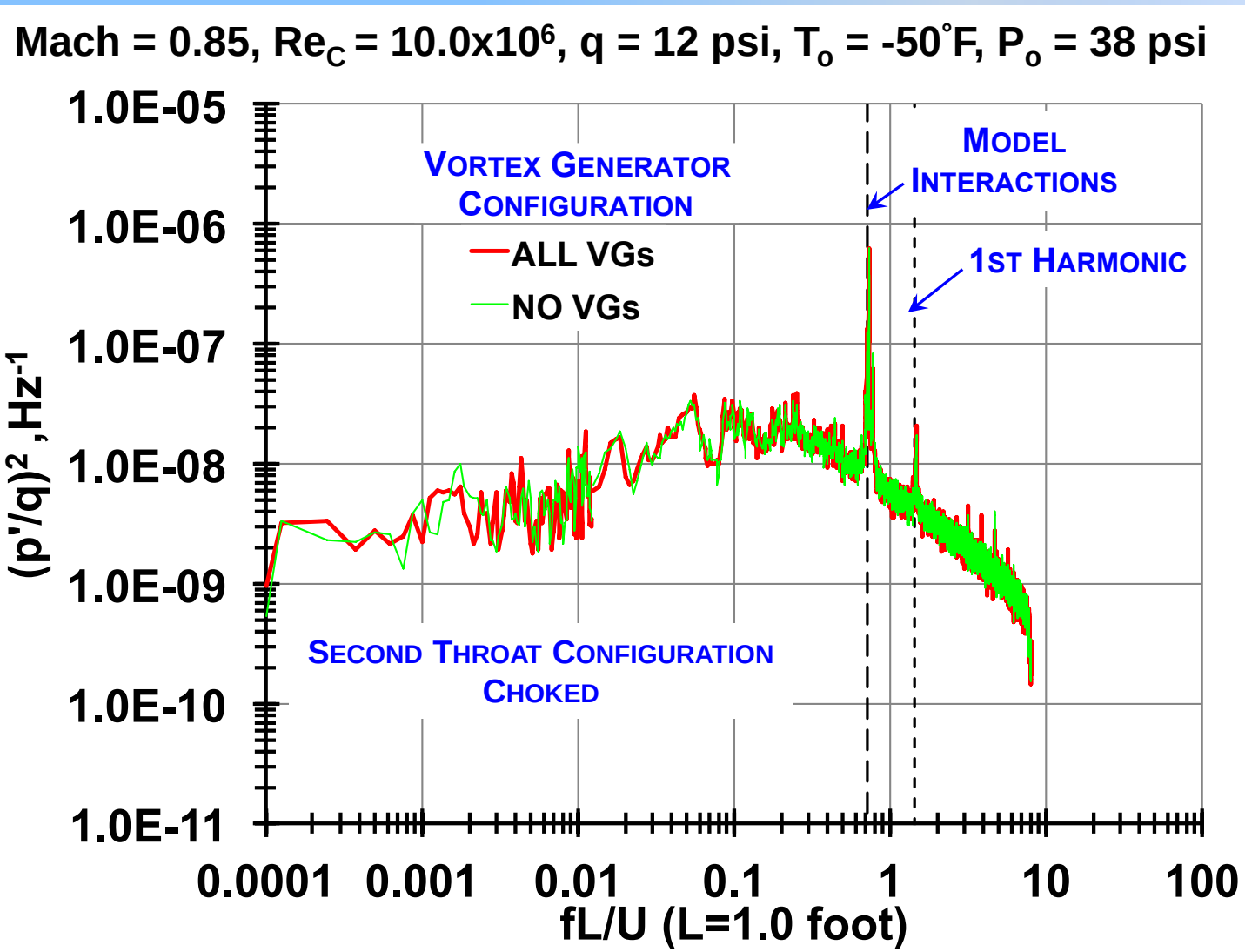




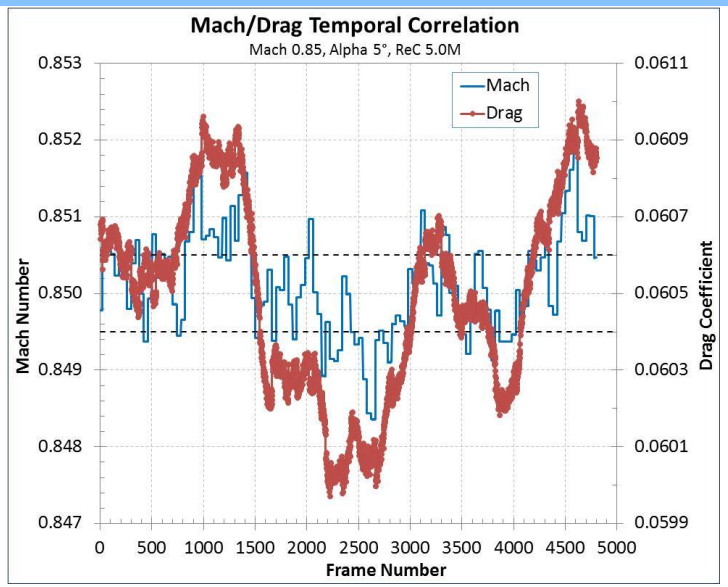
INFLUENCE OF COMMON RESEARCH MODEL



VGs Ineffective with Common Research Model

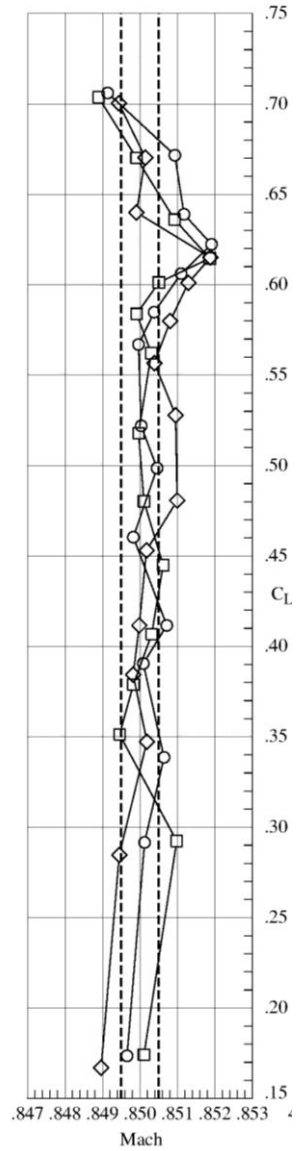


NTF TEST 218 – CRM
CONDITIONAL SAMPLING METHODOLOGY AND EFFECT



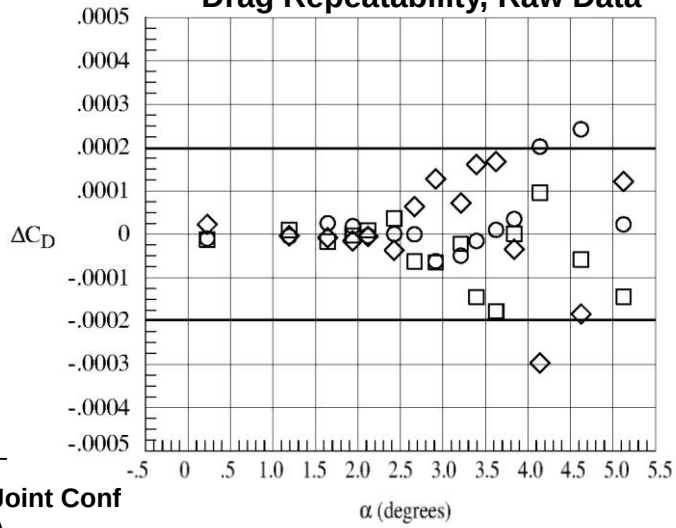
Measured drag force varies directly with measured Mach number variation

Mach variation increases at high AoA, probably due to separation (plot shows 3 repeat runs)

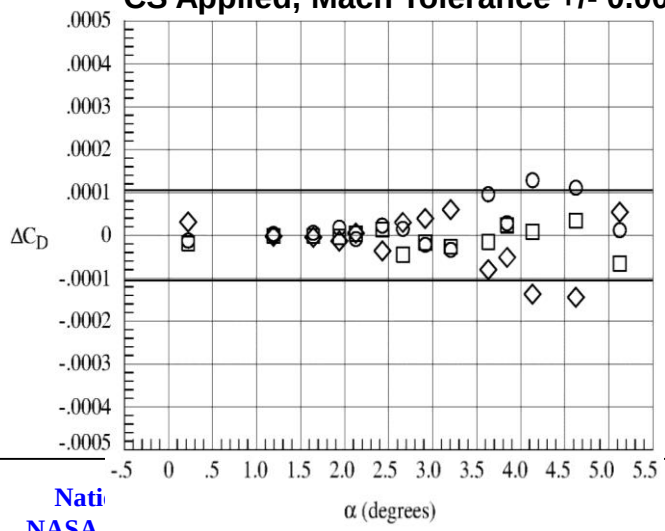


Conditional sampling only accepts and averages frames within a given Mach tolerance – given the correlation between Mach and drag, repeatability is improved

Drag Repeatability, Raw Data



CS Applied, Mach Tolerance +/- 0.0005



SUMMARY

- **STARBUKS effort finished testing 27 September**
  - **Check Standard Model (CSM), Common Research Model (CRM), Centerline Pipe Calibration (CPC) and Flow Uniformity tests (Rake) have been completed**

- **FIDO effort continues**
  - **Desired data quality levels were achieved within series using computational and/or physical means**
    - Preliminary Mach number variability to less than ±0.0005
    - Preliminary C_D repeatability to less than ±0.0001 at cruise conditions

- **Physical Means include VGs and 2nd Throat**
  - **VGs were very effective in stabilizing low frequency characteristics associated with the high speed diffuser for empty tunnel configurations**
  - **VGs were NOT effective for the CRM transonic configuration**
  - **Choked second throat stabilized low frequency wind tunnel characteristics improving Mach number stability**

QUESTIONS?

RESEARCH TEAM

Eric Walker, Ph.D.
Greg Jones, Ph.D.
David Chan
S. Balakrishna , Ph.D.
Joshua DeMoss, Ph.D.
Scott Goodliff
Matthew Bailey
Roman Paryz

AIAA 2015-1557 JONES, ET.AL.
AIAA 2015-0622 CHAN, ET.AL.
AIAA 2014-1481 Paryz

BACKUP SLIDES

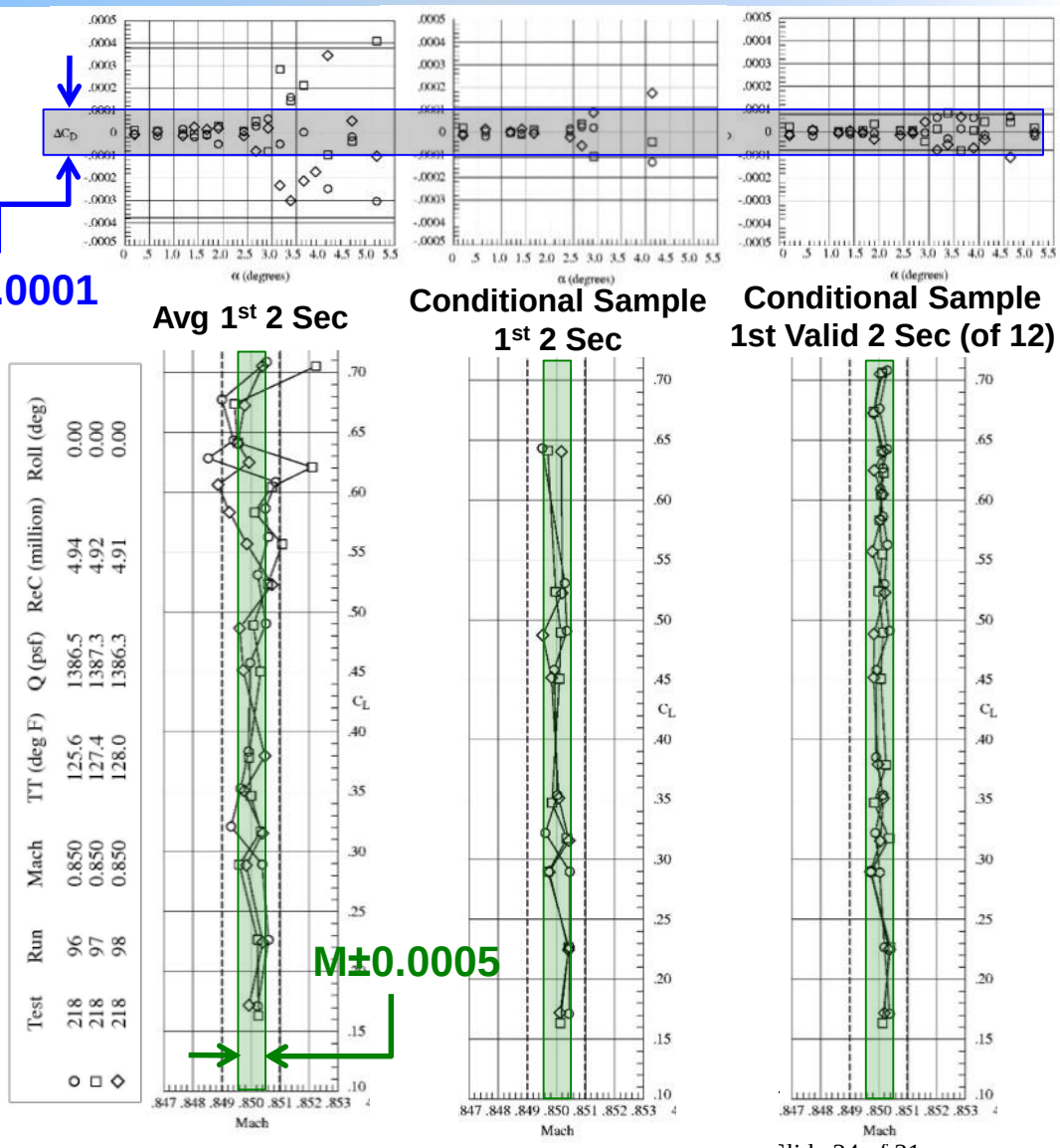
FIDO Projects and Tests

- 5 Major Projects
  - Test Section Movables (2nd Throat)
    - Tunnel configuration selection
    - Mach control methodology
    - 2nd throat actuation
  - Conditional Sampling
    - Off-line [Complete]
    - On-line real-time
  - Increasing Access Housing Heating
  - Proportional Liquid Nitrogen (LN2) Injection
    - Optimized nitrogen injection
    - Minimize nitrogen system hammering
  - LN2 Pump Health Monitoring

- 5 Experimental Entries
  - Test 219 Check standard [Pathfinder]
    - Mach control methodology
    - Continuous sweep optimization
  - Test 216A&B Flow survey rake
    - Validate RTD array
    - Verify turbulence reduction from STARBUKS [Deferred due to budget]
  - Test 220 Calibration extension
    - Mach control methodology
  - Test 221 CRM validation
    - Validation of combined system upgrades

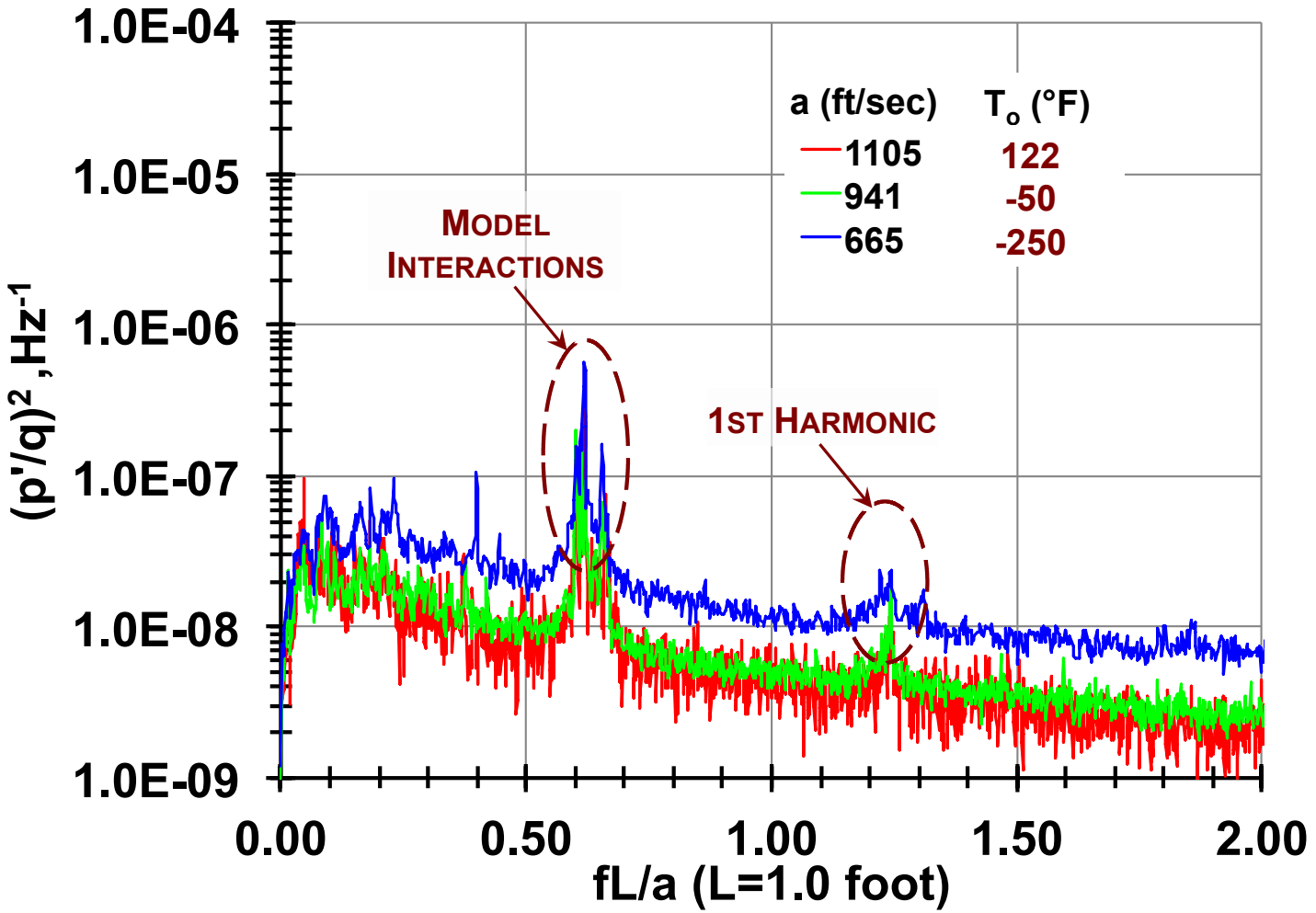
CONDITIONAL SAMPLING

- **Improve data quality**
  - Reject data samples that do not meet requirements
- **Off-line: available**
  - Performance penalty due to longer data samples required
  - Need ~2 seconds of valid data
  - May need to acquire 10-12 sec
- **On-line: in development**
  - Stop acquiring data when samples meet specified criteria
  - Alleviates most of performance penalty



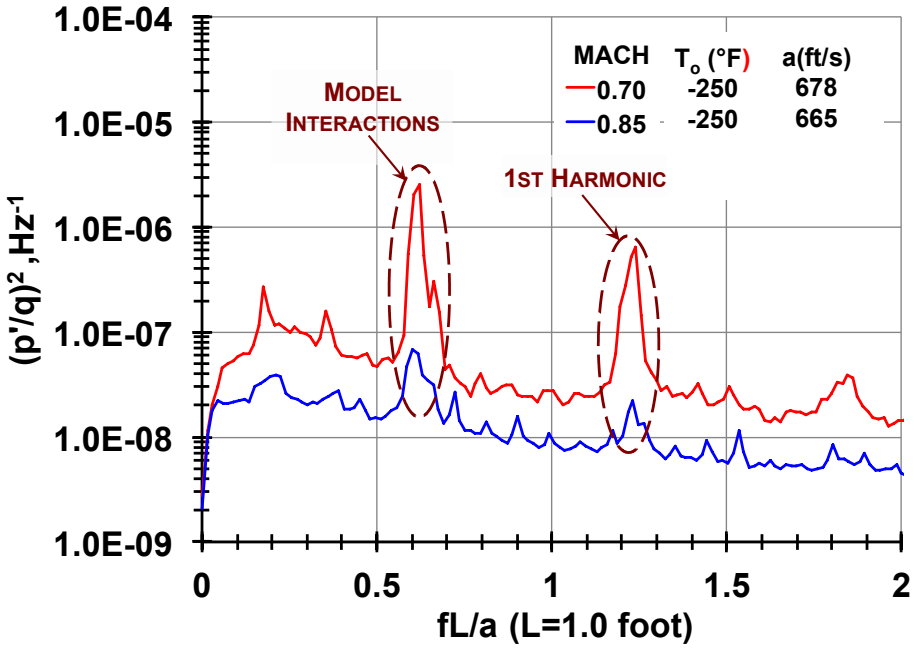
CORRELATION TO THE SPEED OF SOUND

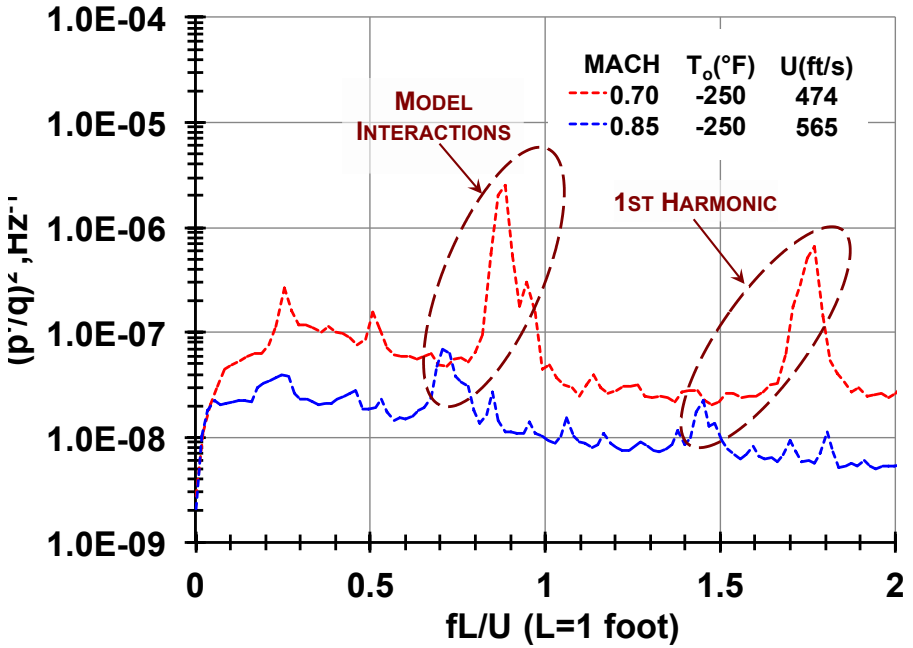
MACH = 0.85, RE_C = VARY, STATION 13 FAR WALL, CHOKED CONFIGURATION



CORRELATION WITH FREE STREAM VELOCITY

MODEL INTERACTIONS ARE NOT CORRELATED WITH MACH NUMBER





Station 13 Far Test Section Wall